Fifth Quarterly Report

for

# SOLAR CELL COVER GLASS DEVELOPMENT

(1 October 1967 through 1 April 1968)

**Contract Number: NAS5-10236**

**Prepared by:**

**Ion Physics Corporation**
**Burlington, Massachusetts**

**Prepared for:**

**Goddard Space Flight Center**
**Greenbelt, Maryland**



ION PHYSICS CORPORATION IPC

A Subsidiary of High Voltage Engineering Corporation

BURLINGTON, MASSACHUSETTS

Quarterly Technical Progress Report No. 5

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National Aeronautics and Space Administration
Goddard Space Flight Center
Greenbelt, Maryland

Contract NAS5-10236

Project Manager: Roger W. Sudbury
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ION PHYSICS CORPORATION
BURLINGTON, MASSACHUSETTS

# OBJECTIVE

The objective of this program is refinement and economic optimization of techniques for fabrication of thick integral coverslips for silicon solar cells. An a priori assumption is that integral coverslip cells must show a definite superiority over conventional glued coverslip cells. The consequences of this assumption provide natural guidelines for selection of candidate coverslip materials, possible fabrication techniques and environmental test end points. Specifically, all coverslip materials that are known to significantly degrade under ultraviolet, proton or electron irradiation must be categorically excluded from consideration. Similarly, all fabrication techniques that are inherently deleterious to the cell structure itself must be rejected. Finally, the environmental and radiation test end points must be at least as severe as those encountered with glued coverslip cells. For ease in comparison, final testing is to be done on cells with 6 mil integral coverslips.

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# SECTION 1

# INTRODUCTION

This report covers two quarterly reporting periods. During the first period, the level of effort on the program was reduced and no separate report was issued for that period.

High vacuum sputtering of integral coverslips has continued in the new enlarged sputtering system shown in the Fourth Quarterly Report. During this period, the system was automated to allow continuous running without an operator. Troubleshooting of the new system resulted in excessive downtime during initial running that is not anticipated to re-occur. The coverslipping results are described in detail in Section 2. The contamination that occurred degraded the cells significantly and did not justify increasing the coverslip thickness beyond 2 mils when the cells were removed for test.

Equipment is being modified for rf and rf-dc reactive sputtering. Satisfactory operation of the rf equipment has not been achieved and as a result an evaluation of commercially-available equipment has been conducted.

While equipment problems have delayed the fabrication of thick integral coverslips, work has continued on testing and evaluation of coverslipped cells. Only $SiO_2$ was considered in this work. Two of the major problems are film stress and film quality.

The stress resulting from the high vacuum sputtering technique has been documented. Considerable variation in the stress across the 33 cm sample mounting platen has been observed. Figure 1 indicates the variation in cell bow. This variation is consistently observed and correlates with an asymmetry in the high vacuum sputtering system. It is believed that the correlation may provide an insight into the cause of the stress and a scheme for reducing it.

The quality of the high vacuum sputtered film from the new machine indicated a problem with absorption and an evaluation was conducted. The analysis is discussed in Section 2. One potential source of the problem has been identified and corrections are being made to the system.

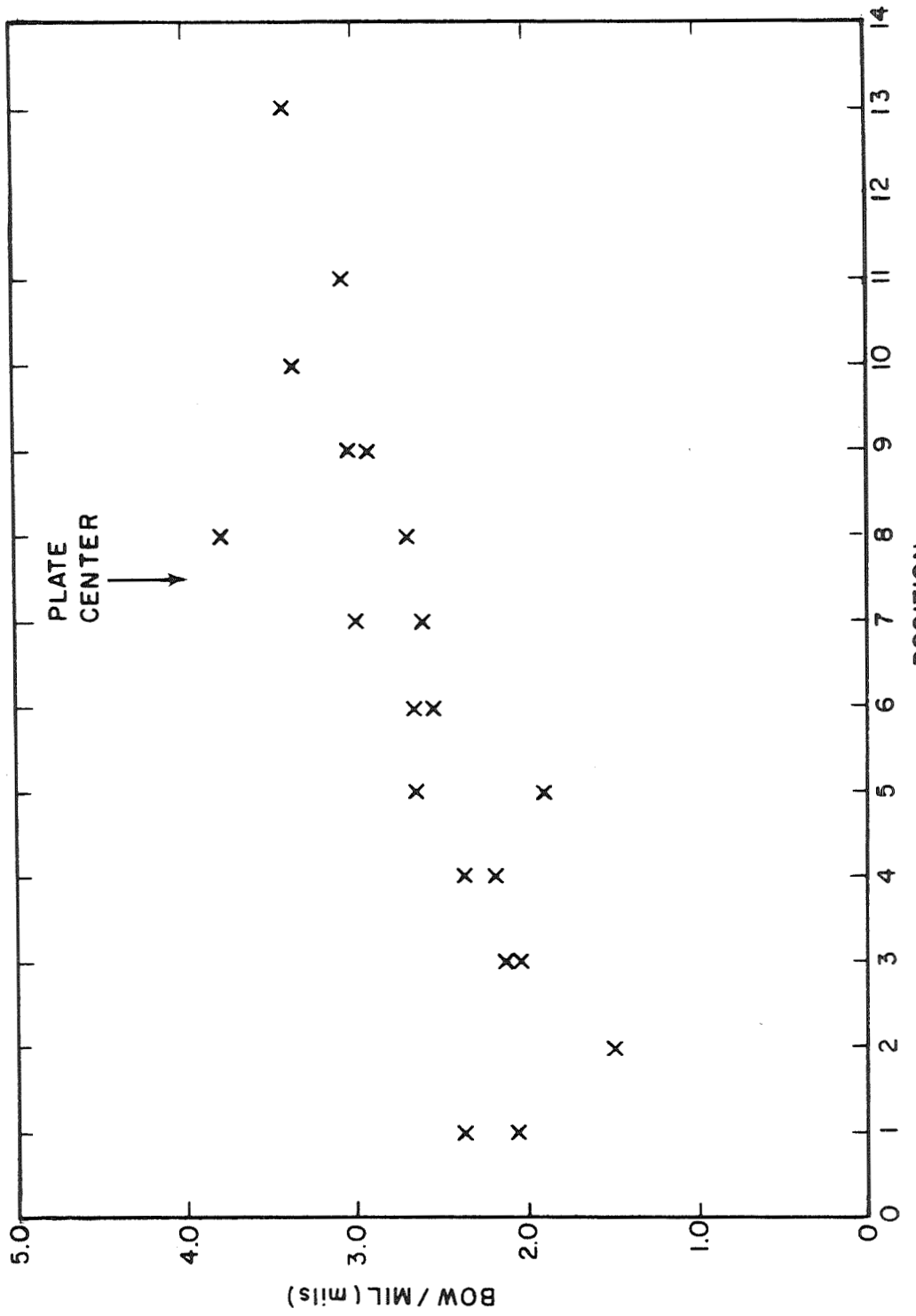


Figure 1. Coverslip Cell Bow - Production Machine

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# SECTION 2

# TECHNICAL DISCUSSION

## 2.1 Stress Analysis

Experimental cell curvature versus coverslip thickness data was presented in Figure 2 of Quarterly Report No. 4. Regression techniques have been used to obtain best fit polynomials for the data. The first and second order best fit polynomials found are:

$$(1) \quad z = 3.45\,d - 1.15$$

$$(2) \quad z = 0.15\,d^2 + 2.41\,d + 0.46$$

where z is cell bow as measured by the clamped end technique and d is coverslip thickness. These fitted polynomials have not been forced to pass through the origin. The straight line (1) is a good approximation for the purpose of stress calculation and is shown in Figure 2. This straight line can be taken to represent the IPC high vacuum sputtered integral coverslip results.

The maximum stress, $S_{max}$, in the silicon of a solar cell stressed to radius r is approximately given by:

$$S_{max} = \frac{2}{3}\,\frac{E_s\,t}{r} \tag{1}$$

where $E_s$ is Young's modulus of silicon ($1.24 \times 10^{12}$ dynes/cm$^2$ for the $\langle 111 \rangle$ plane) and t is the silicon thickness. Radius of curvature is related to bow z as:

$$r = \frac{\ell^2}{2z} \tag{2}$$

where $\ell$ is the length of the curved edge (2 cm). Introduction of the experimental data best fit straight line into (1) and (2) results in the plot, shown in Figure 3, of maximum silicon stress as a function of slip thickness.

The peak stress in silicon is presented in pounds/square inch for comparison with the stress found by others. While it appears the high vacuum sputtered film is significantly strained, a direct comparison with other data depends on the equation and constants chosen for the calculation.

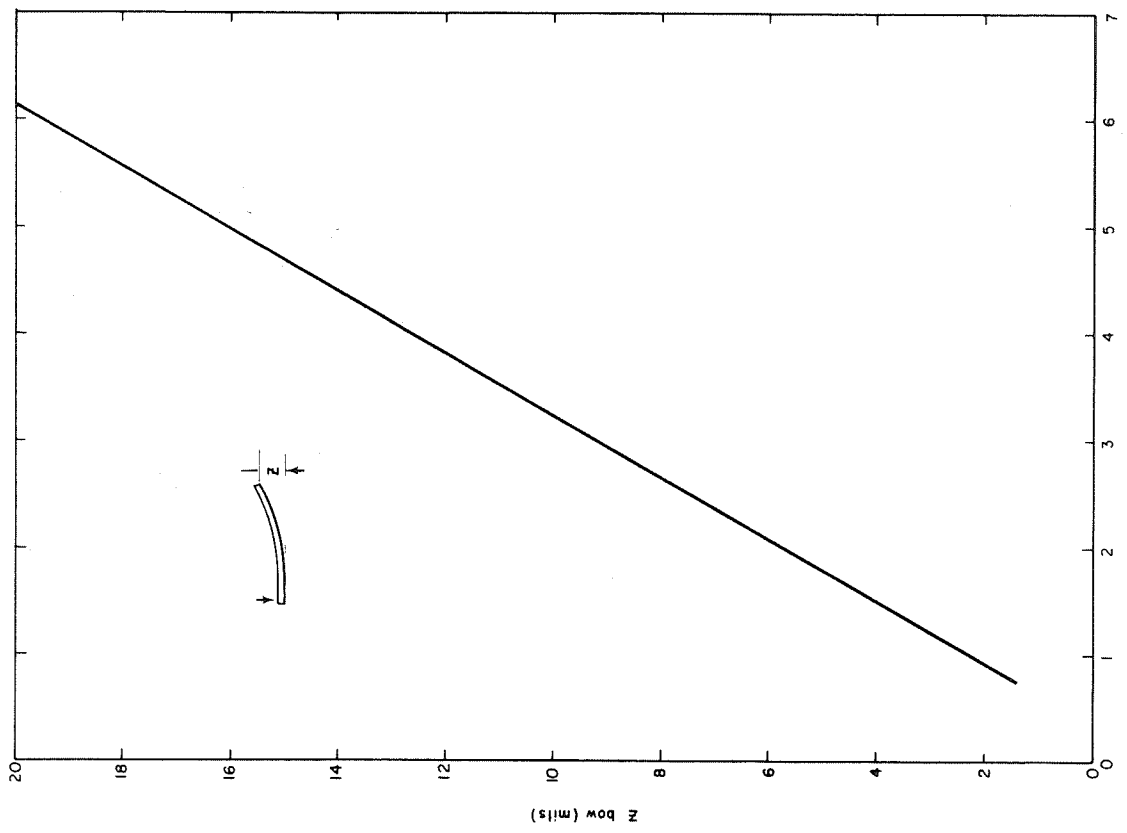


Figure 2. Best Straight Line Fit of Experimental Cell Bow vs Coverslip Thickness Data

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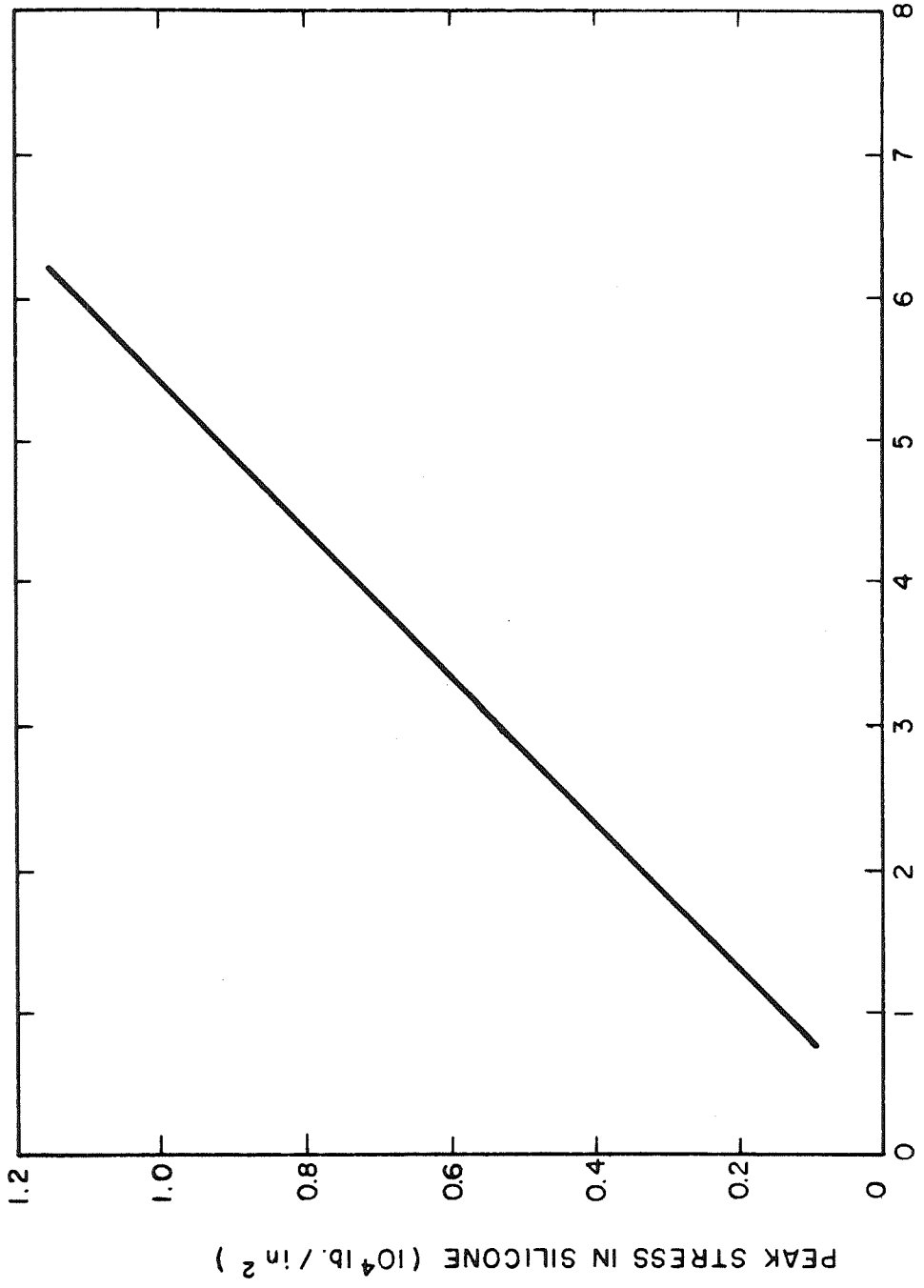


Figure 3. Peak Silicon Stress vs Coverslip Thickness

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## 2.2 High Vacuum Sputtered Coverslips

Coverslipping was begun in the new beam sputtering production coverslipping machine during the quarter. Thick integral coverslips were to be obtained by cycling cells through 2 mil integral coverslipping production runs. When the first 200 hour run was completed, the $SiO_2$ indicated a significant yellowing. The cells were removed and electrical tests made. A significant decrease in efficiency was found. In previous coverslipping runs, a slight loss in efficiency has been generally detected when an increase would be expected with the $CeO_2$ coating. For the first 200 hour run a significant loss (about 67%) in efficiency was measured.

To determine the quality of the $SiO_2$, an optical analysis has been carried out on these and other samples. The light transmission of $SiO_2$ films deposited on Corning No. 7740 fused silica is described for earlier runs, as well as a sample from the production run. The technique is described in Appendix A.

Figures 4a, 4b and 4c display the transmission of a not particularly good early 114 micron thick film (Run No. 11). Figure 4a covers the VIS-UV range (800 to 190 mμ) and illustrates certain features of these films. Most noticeable is a broad absorption peak centered near 560 mμ. This broad line dominates film transmission throughout the visible region by producing a rather flat shoulder in the 400 to 600 mμ region. While the total absorption of this broad line is rather small, even in this case, its effect on cell response would be quite large. (In Figure 5a, this 560 mμ line is barely discernable.) There is a second small, broad absorption line at ~ 620 mμ that cannot be resolved in Figure 4a. (It is, again, barely discernable in Figure 5a.) In samples like that of Run No. 11, the 560 and 620 mμ lines merge to give an absorbing shoulder. Absorption from the 620 mμ line has always been observed to be less than or equal to that of the 560 mμ line. Some samples suggest there is a third broad absorption line at ~ 470 mμ. This line is barely apparent in Figure 5a, and is lost in the tailing of Figure 4a.

These three lines are probably due to metal contamination from stainless steel. Their extreme width suggests that the impurity metals are conjugated with varying length chains of Si atoms or $SiO_2$ molecules since a simple metal-Si species would be expected to produce sharp absorption lines. Identification of these lines is being pursued.

Figures 5a and 5b are the spectrum scans for an earlier good 21 micron film (Run No. 16). From Figure 5a it is seen that there is some transmission tailing in the 300 to 400 mμ region even in a good film. The 300 to 400 mμ region of Figure 4a is seen to be heavily absorbing, but without apparent structure. While it is possible that the Run No. 16 film has a specific absorption peak in this region, it is presently thought that this absorption is due either to the broadness of the $SiO_x$ absorption in the 200 to 300 mμ region or to light

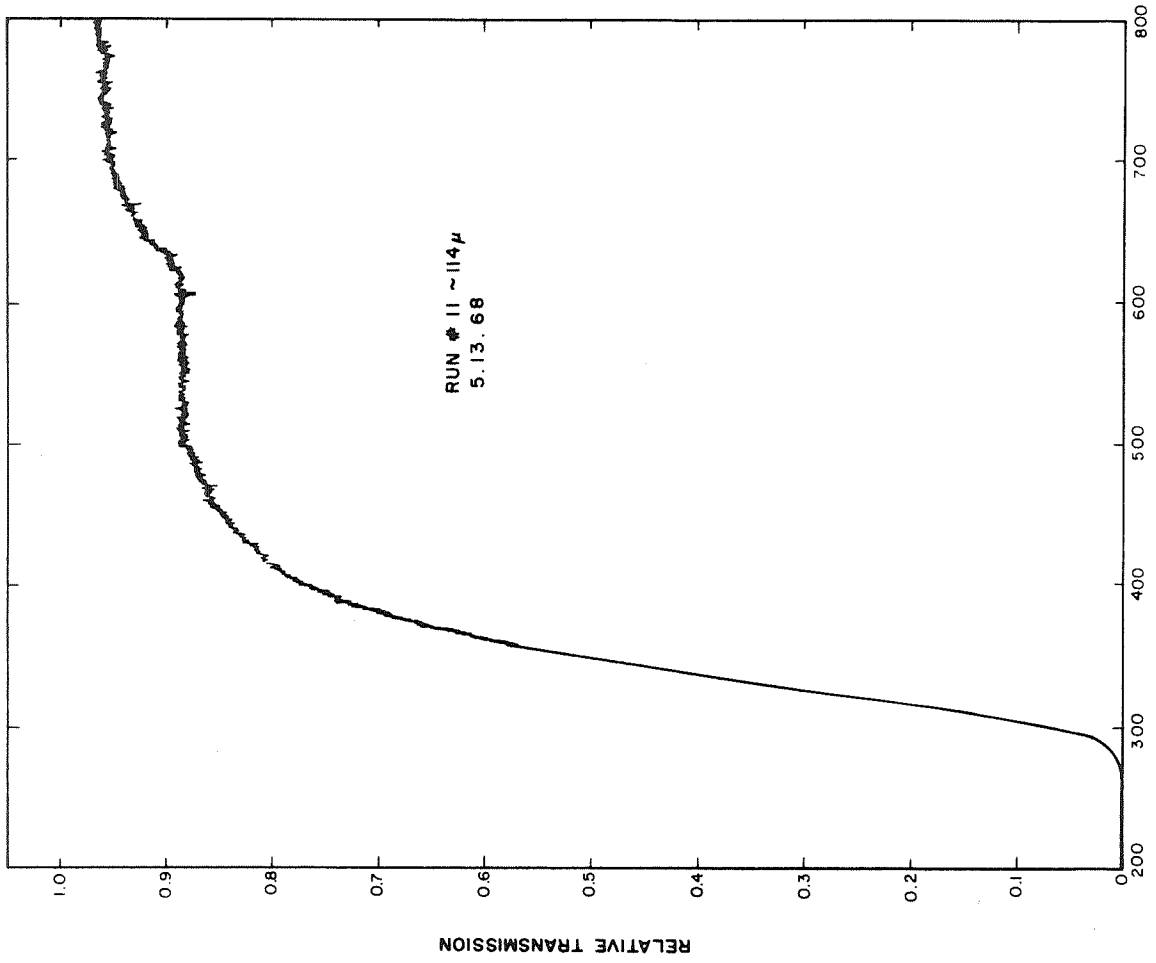


Figure 4a. Optical Transmission Run 11

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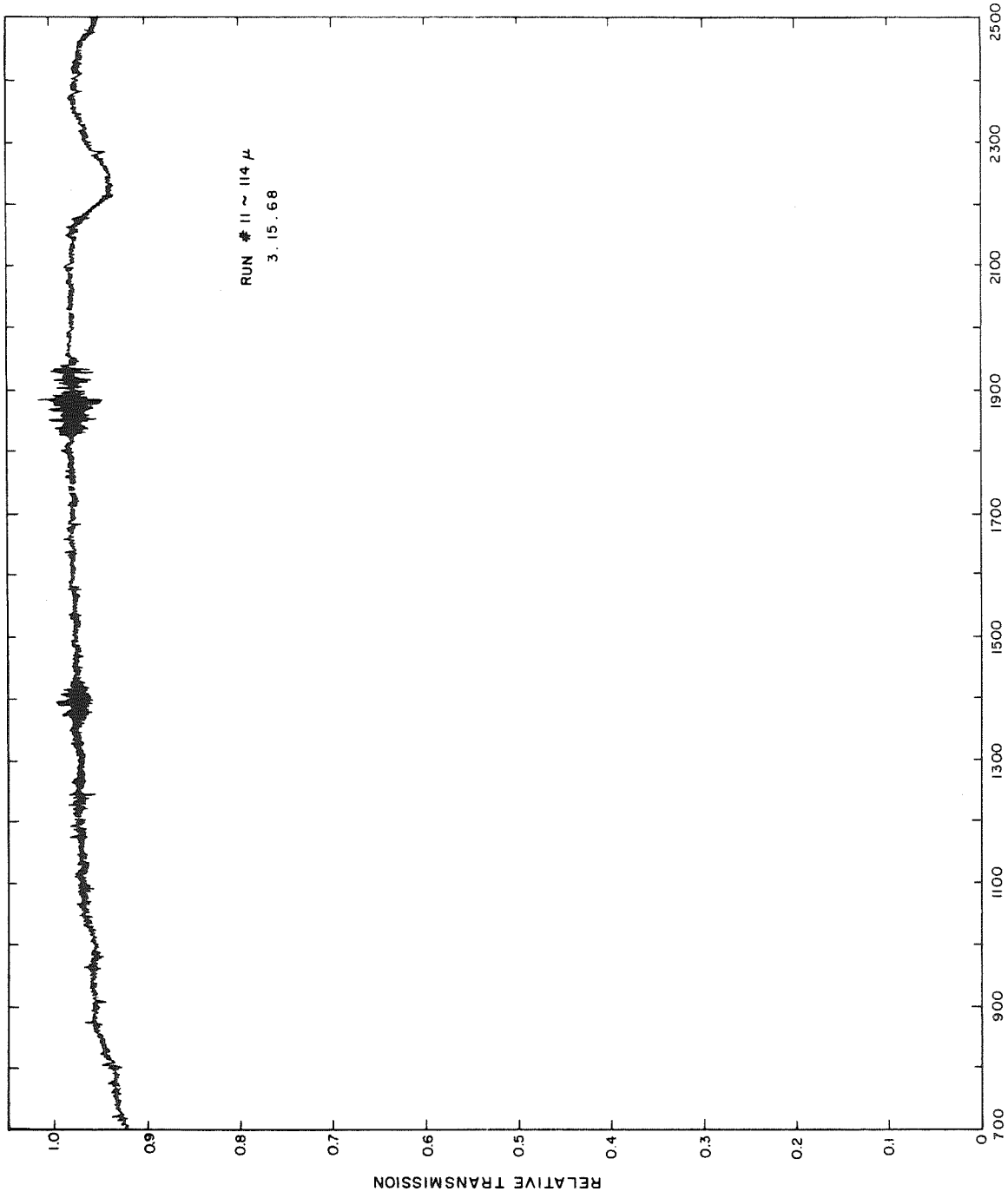


Figure 4b. Optical Transmission Run 11

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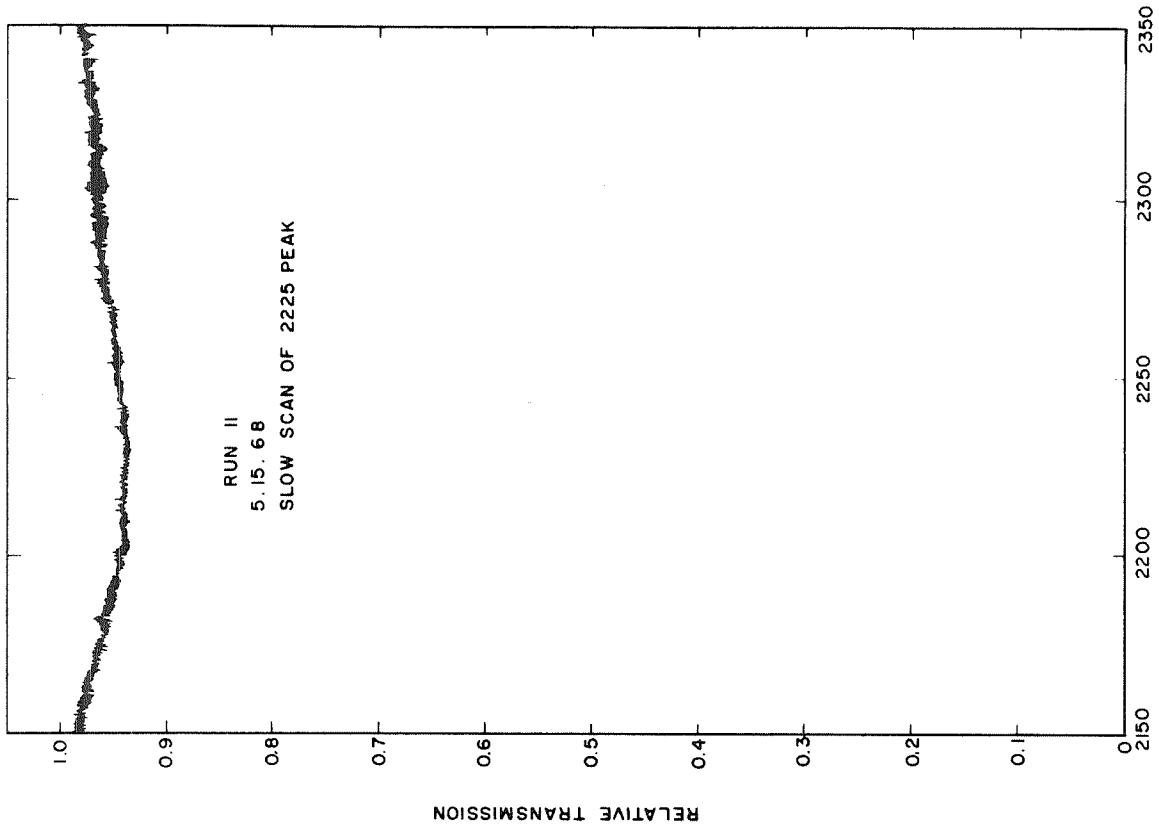


Figure 4c. Optical Transmission Run 11

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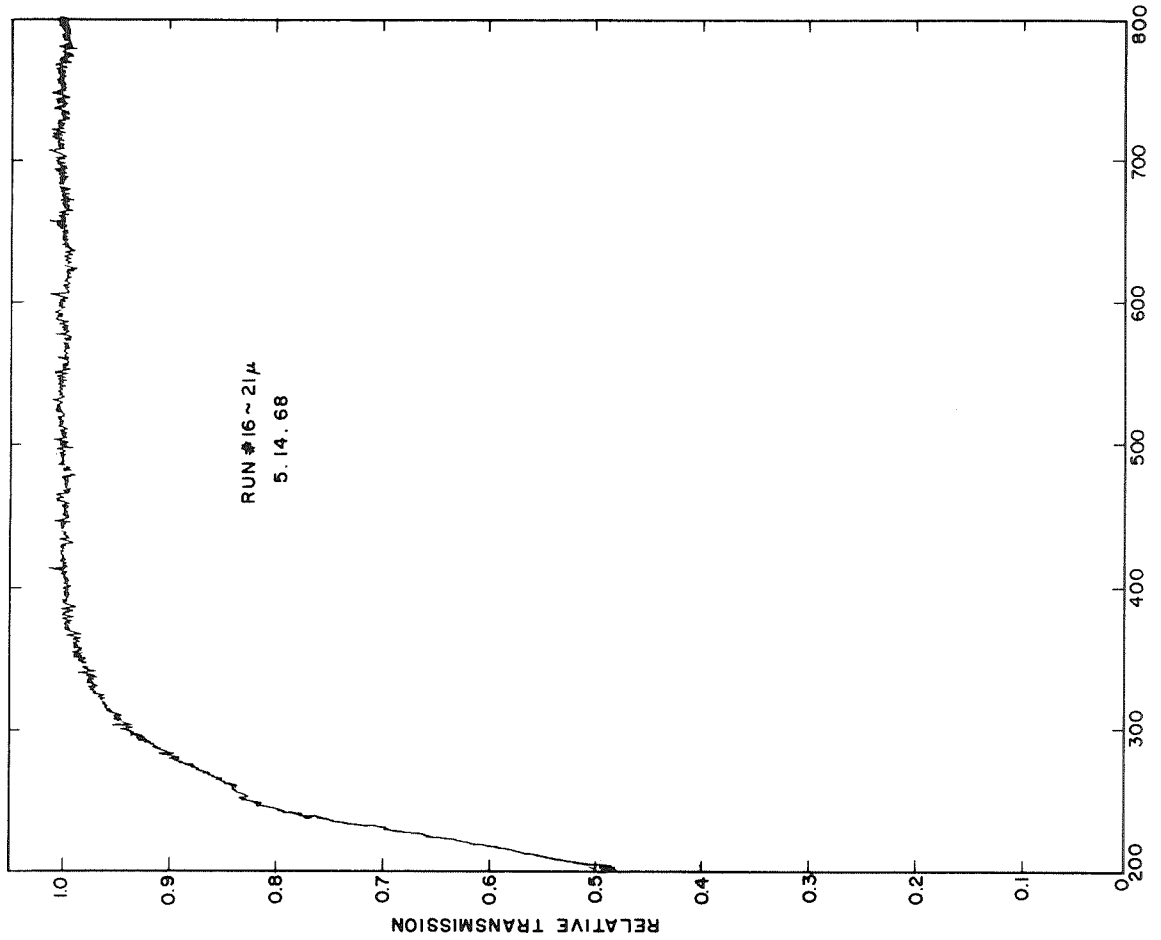


Figure 5a. Optical Transmission Run 16

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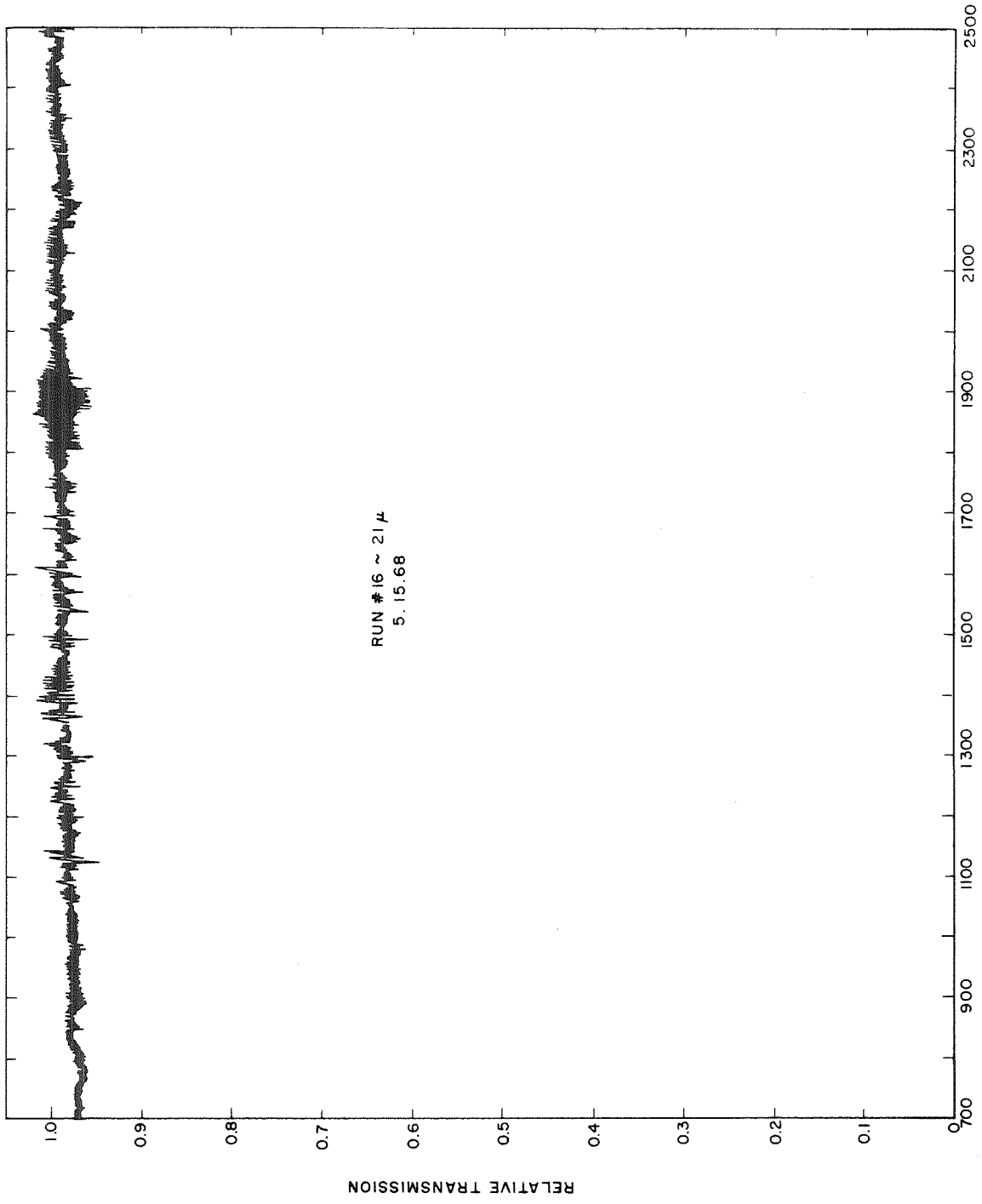


Figure 5b. Optical Transmission Run 16

1-2972

scattering. Reflection measurements that are currently in progress should allow a separation of these two effects. The absorption in the 200 to 300 mμ region has been attributed to $SiO_x$ in the literature.

Figures 4b and 5b are the near-IR scans of Run No. 11 and Run No. 16, respectively. To ~ 1000 mμ they are quite similar. Below this point, Figure 4b suggests a slight tailing that is not really seen in Figure 5b. This could, again, be due to light scattering or to an unidentified specific absorption. In both Figures 4b and 5b, the large bands near 1400 mμ and 1850 mμ are due to atmospheric absorption. (The spectrometer was not purged with dry $N_2$.) The large bands near 2250 mμ are characteristic of fused silica. Figure 4c is an expanded trace of the 2250 mμ band shown in Figure 4b. Beyond these, there are suggestions of absorption bands at 780 to 790 mμ, 990 mμ and 1280 mμ. They are all small and have not been identified.

Figures 6a and 6b are the scans of a poor ~ 58 micron film from the production coverslipping machine. This film was visibly brownish. (The brown film appearance in polychromatic light is due to heavy absorption of the blue end of the spectrum.) From Figure 6b, it is seen that a relatively heavy absorption extends throughout the entire near-IR region. Superimposed on this are the fine features seen in the Figure 4b and 5b traces. Figure 6a shows this absorption tails rapidly across the VIS-UV region. The essentially flat absorption shown in these last two figures suggests either serious light scattering losses or deposition of a thin metal film, unassociated with the $SiO_2$, at some level in the deposited slip. The cause for this behavior is under investigation.

It is readily seen that this run is quite poor in comparison to Run Nos. 11 and 16, and is, in fact, completely unacceptable. Other production machine test runs, of comparable film thickness, have produced films whose transmission falls between that of Run No. 16 and Run No. 11.

It should be stressed that these spectra have been run for purposes of film analysis and quality control. The apparent transmission observed in the scans is less than would be observed on coverslipped cells, since scattered light is lost from the spectrometer measurements while, due to the small spacing between the scattering centers in the slip and the cell, some of the scattered light would be absorbed in the cell.

## 2.3 Antireflection Coating

Previous discussions in Quarterly Technical Progress Report No. 4 indicate the advantage of the use of $CeO_2$ antireflecting coating between the silicon and $SiO_2$. This has been documented by IPC and the pertinent results are shown in Figure 7 which indicates the results of cells taken from two lots one-half of which were antireflective coated with $CeO_2$ and one-half coated with

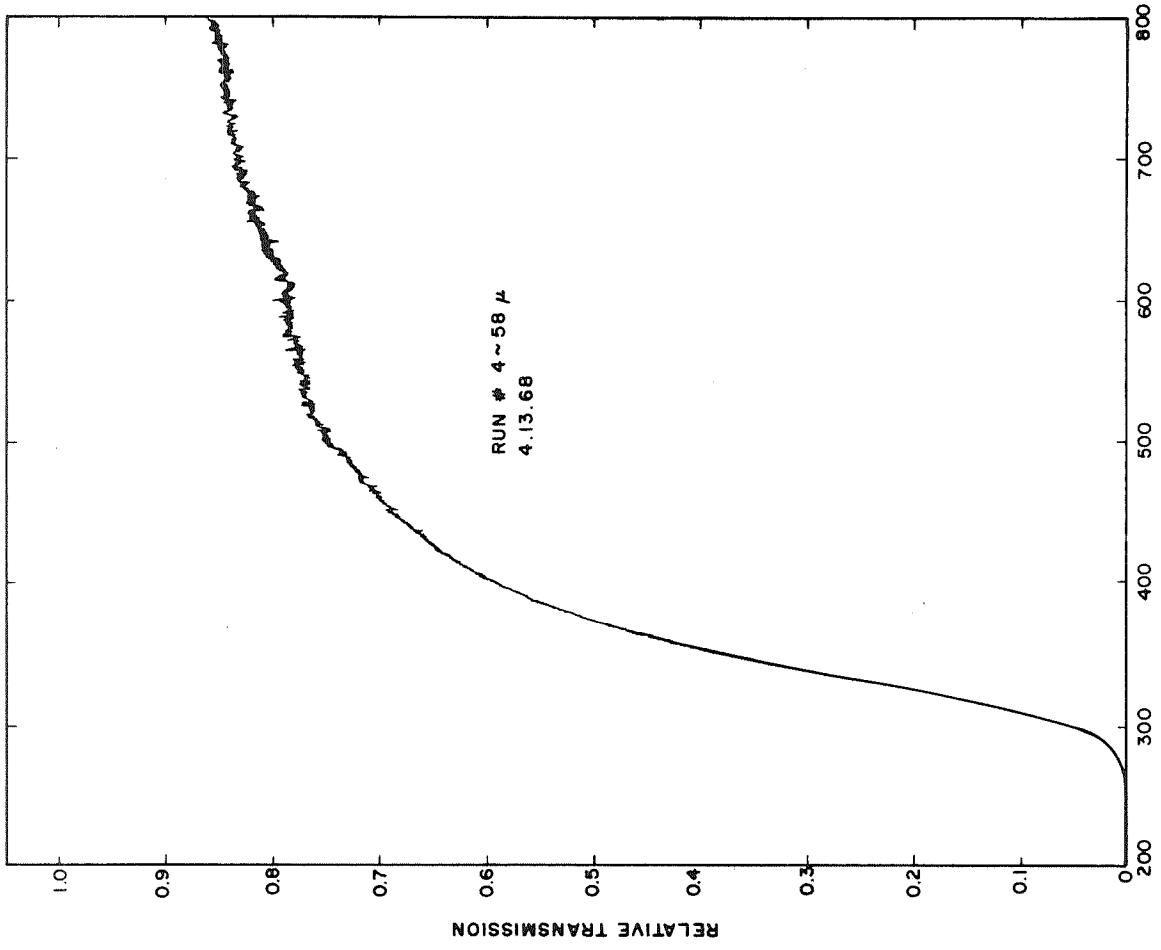


Figure 6a. Optical Transmission Test Run (Production Machine)

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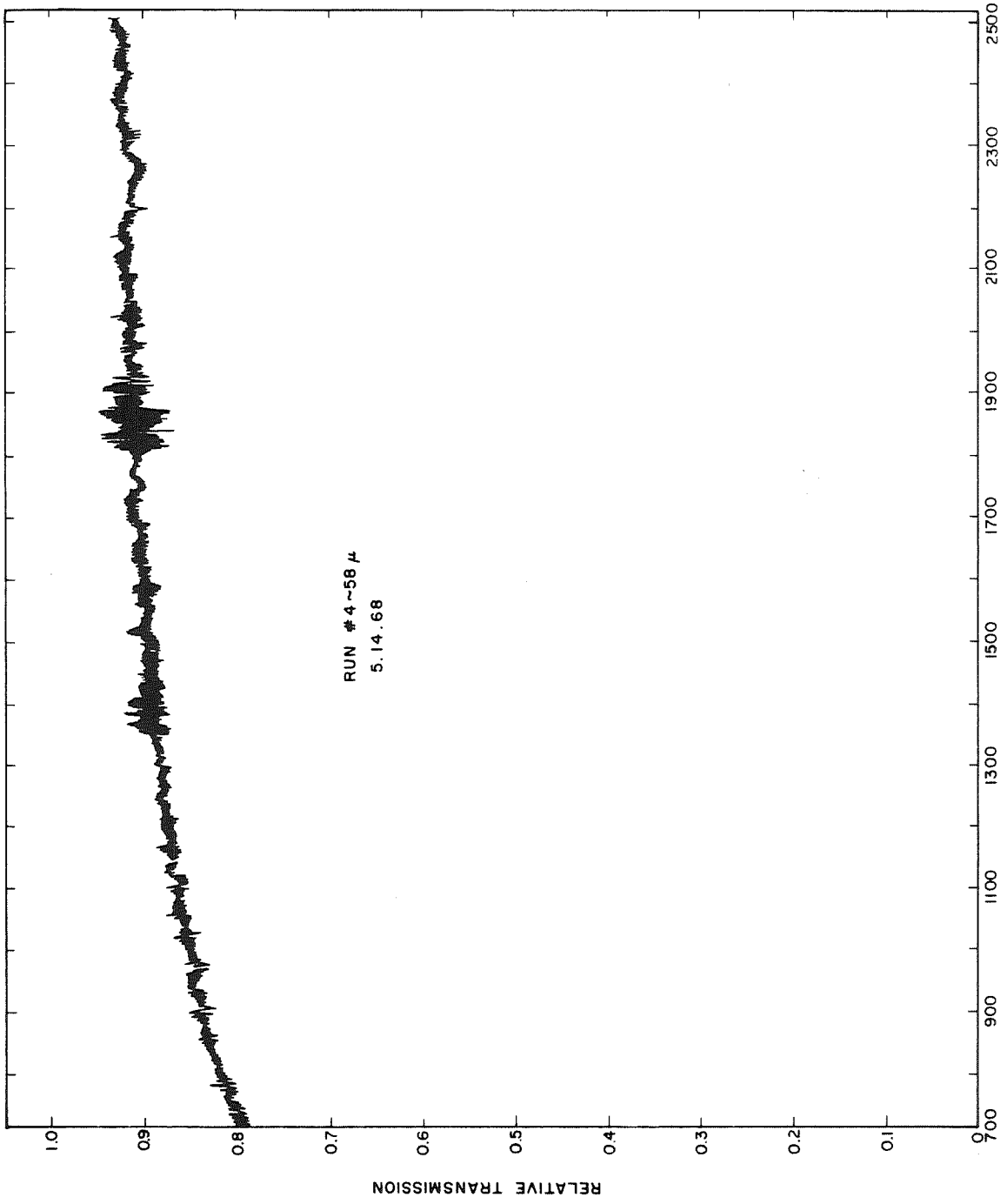


Figure 6b. Optical Transmission Test Run (Production Machine)

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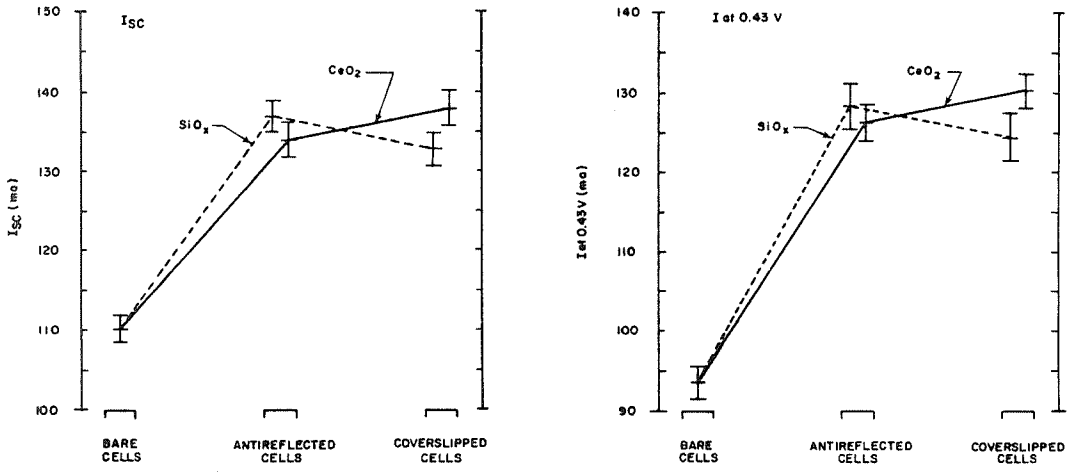


Figure 7. Antireflection Coating Effectiveness

$SiO_x$. The data is summarized in Table 1. The results with coverslips were obtained by applying OCLI coverslips of Corning 7940 with GE RTV602.

For integral coverslipped cells, the improvement indicated above has not been consistently demonstrated. In general, the cells have changed little or slightly degraded on application of the coverslip. A large degradation recently observed due to optical absorption has been previously discussed.

The standard glued coverslips have an antireflection coating of $MgF_2$. This is a common coating in the optical industry to reduce reflection at quartz air interfaces. An improvement in integral coverslipped solar cells can be obtained by application of $MgF_2$ to the $SiO_2$. The theoretical improvement is indicated in Figure 8. Integral coverslipped cells have been coated with $MgF_2$ with before and after electrical data listed in Table 2.

## 2.4 Ultraviolet Vacuum Testing

Another 100°C vacuum-UV test was run during the quarter for 560 hours. The equipment was described in Quarterly Report No. 3. Eight cells were used for the test. Four of the cells had integral coverslips of 2 mil thickness and four had only the $CeO_2$ antireflection coating. The results of the test are tabulated in Table 3. No measurement degradation was evident.

## 2.5 Proton Resistance

Quarterly Report No. 4 provided information on the degradation from low energy protons of cells with exposed unsoldered contact bars and indicated the necessity for protecting the back surface contact.

Protection of the contact bar with solder can solve part of the problem. Often with glued coverslips a region of the cell is exposed between the contact bar and cover glass. In application of an integral cover glass it is possible to protect the cell with a coating that partially covers the contact bar reducing the exposed gap to zero.

An example of the degradation that can be expected from an exposed area is indicated in results from Air Force Contract F33615-68-C-1164, where a strip was exposed to 400 kV protons as shown in Figure 9. The results are shown in Table 4 and indicate a degradation in cell efficiency, a slight improvement above $10^{13}$ p/cm$^2$ in the efficiency has been noted but complete recovery is neither achieved or expected.

Table 1. Experimental Data Summary

| | | | Isc (ma) | | I @ 0.43 V (ma) | |
|---|---|---|---|---|---|---|
| | | | Average | Std Deviation | Average | Std Deviation |
| Bare Cells | $CeO_2$ Cells | Lot 254 (23 cells) | 99.26 | 1.45 | 93.78 | 1.51 |
| | | Lot 255 (20 cells) | 101.20 | 1.88 | 94.50 | 1.73 |
| | | Both Lots (43 cells) | 100.16 | 2.13 | 94.12 | 1.64 |
| | $SiO_x$ Cells | Lot 254 (23 cells) | 99.35 | 1.56 | 92.87 | 2.32 |
| | | Lot 255 (20 cells) | 100.50 | 1.76 | 93.65 | 2.48 |
| | | Both Lots (43 cells) | 99.88 | 1.73 | 93.23 | 2.40 |
| | All Bare Cells (86 cells) | | 100.02 | 1.82 | 93.67 | 2.09 |
| Anti-reflected Cells | $CeO_2$ Cells | Lot 254 (23 cells) | 132.91 | 1.70 | 125.30 | 2.05 |
| | | Lot 255 (20 cells) | 135.15 | 2.03 | 127.45 | 1.85 |
| | | Both Lots (43 cells) | 133.95 | 2.16 | 126.30 | 2.22 |
| | $SiO_x$ Cells | Lot 254 (23 cells) | 136.65 | 2.23 | 127.39 | 3.06 |
| | | Lot 255 (20 cells) | 137.25 | 1.65 | 129.35 | 2.13 |
| | | Both Lots (43 cells) | 136.93 | 1.98 | 128.30 | 2.82 |
| Conventionally Coverslipped Cells | $CeO_2$ Cells | Lot 254 (23 cells) | 136.52 | 1.44 | 129.26 | 1.68 |
| | | Lot 255 (20 cells) | 139.60 | 1.82 | 131.30 | 1.98 |
| | | Both Lots (43 cells) | 137.95 | 2.24 | 130.21 | 2.08 |
| | $SiO_x$ Cells | Lot 254 (23 cells) | 132.61 | 2.44 | 123.78 | 3.38 |
| | | Lot 255 (20 cells) | 133.15 | 1.53 | 125.45 | 2.37 |
| | | Both Lots (43 cells) | 132.86 | 2.07 | 124.56 | 3.04 |

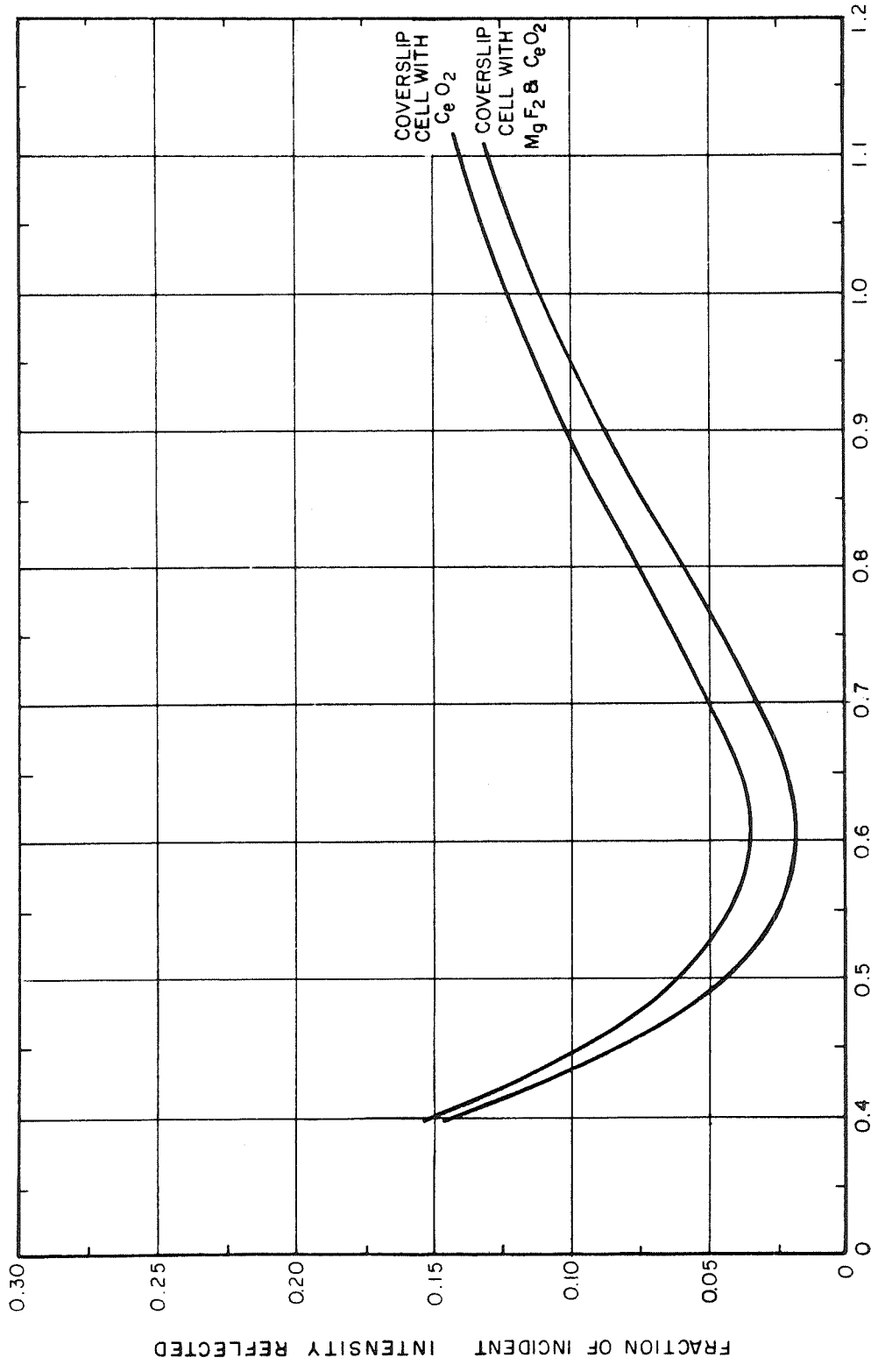


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Figure 8. Calculated Fraction of Incident Intensity Reflected from Coverslip Cells

Table 2. $MgF_2$ Coating Results

| | 43, 2 x 2 cm Integral Coverslip Cells Tested | | Change after Application of $MgF_2$ |
|---|---|---|---|
| | Arithmetic Mean | Standard Deviation | |
| $I_{sc}$ Before | 135.8 ma | 2.2 ma | |
| $I_{sc}$ After | 138.0 | 2.1 | 1.6% |
| $I_{0.43}$ Before | 124.3 ma | 1.8 ma | |
| $I_{0.43}$ After | 125.7 | 1.6 | 1.1% |

Table 3. Vacuum UV Storage No. 4

| Cell | Type | $I_{SC}$ | | $I_{0.43}$ | | $V_{OC}$ | | $\eta$ at 0.43 Volts | |
|---|---|---|---|---|---|---|---|---|---|
| | | Initial (ma) | Final (ma) | Initial (ma) | Final (ma) | Initial (volt) | Final (volt) | Initial (%) | Final (%) |
| T4-17 | Regular no coverslip | 138 | 135 | 122 | 122 | 0.543 | 0.544 | 9.9 | 9.9 |
| T4-18 | Regular no coverslip | 133 | 133 | 120 | 120 | 0.544 | 0.545 | 9.7 | 9.7 |
| T4-19 | Regular no coverslip | 133 | 131 | 120 | 120 | 0.540 | 0.538 | 9.7 | 9.7 |
| T4-20 | Regular no coverslip | 135 | 133 | 122 | 123 | 0.545 | 0.544 | 9.9 | 9.9 |
| T5-2 | 2 mil coverslip | 134 | 135 | 126 | 128 | 0.548 | 0.548 | 10.2 | 10.2 |
| T5-3 | 2 mil coverslip | 129 | 132 | 121 | 122 | 0.548 | 0.549 | 9.8 | 9.8 |
| T5-4 | 2 mil coverslip | 135 | 136 | 125 | 127 | 0.553 | 0.555 | 10.1 | 10.1 |
| T5-6 | 2 mil coverslip | 139 | 139 | 127 | 124 | 0.549 | 0.550 | 10.3 | 10.3 |

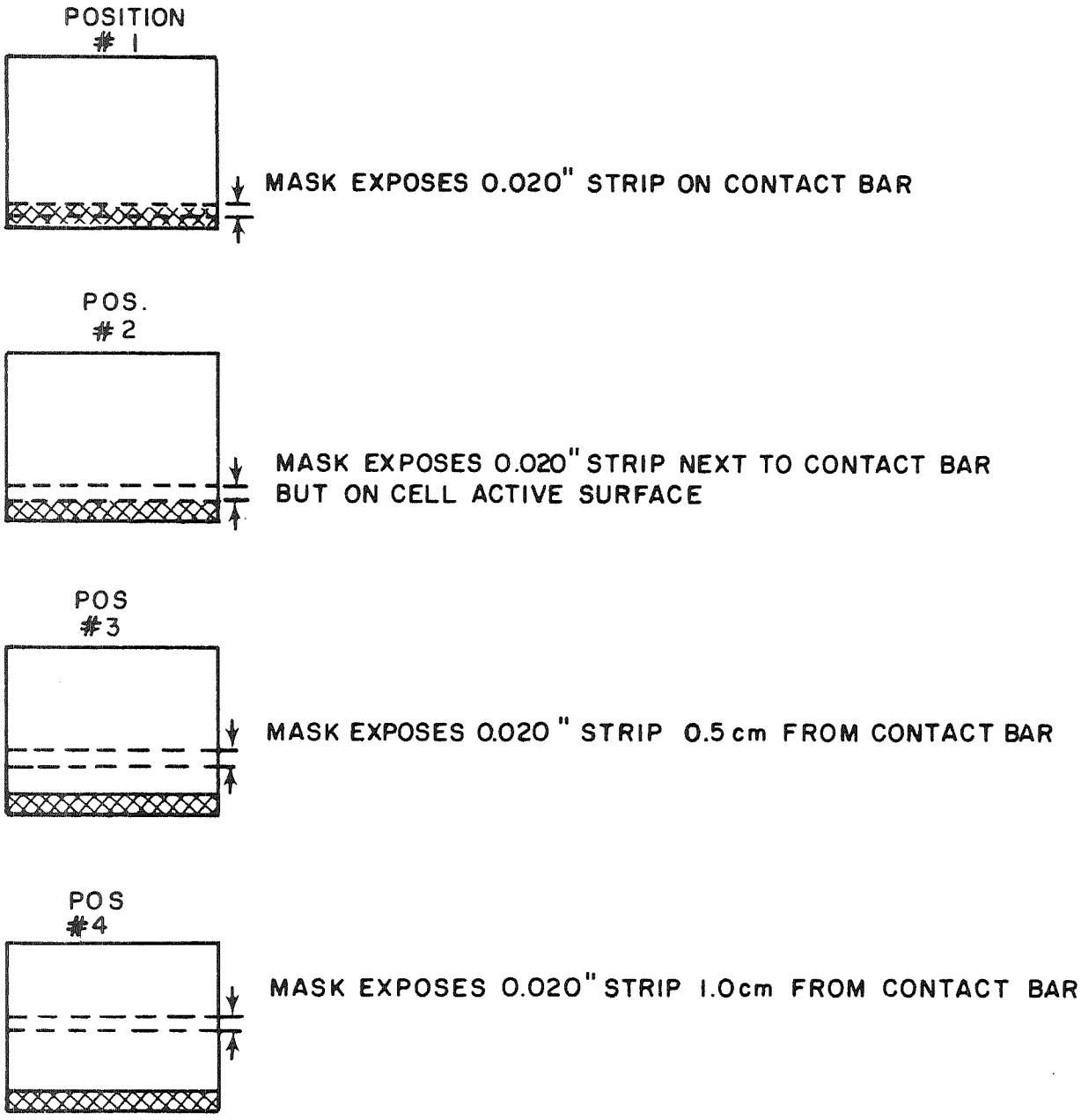


Figure 9. Proton Strip Mask

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# Table 4. Strip Irradiation Results

| Run Number | Mounting Block Temperature | Cell | Position Number | Test | Proton Fluence ($p/cm^2$) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0 (Initial) | $10^{11}$ | $10^{12}$ | $10^{13}$ | $10^{14}$ | $10^{15}$ |
| 1 | 20°C | T4-16 | 1 | $I_{sc}$ | 133 ma | 133 ma | 132 ma | 131 ma | 131 ma | |
| | | | | $I_{0.43}$ | 128 ma | 127 ma | 122 ma | 113 ma | 112 ma | |
| | | | | $V_{oc}$ | 0.554 V | 0.551 V | 0.545 V | 0.544 V | 0.541 V | |
| | | | | $\eta$ at 0.43 V | 10.4% | 10.3% | 9.9% | 9.1% | 9.1% | |
| | | T4-14 | 2 | $I_{sc}$ | 134 ma | 135 ma | 132 ma | 133 ma | 132 ma | |
| | | | | $I_{0.43}$ | 128 ma | 127 ma | 121 ma | 114 ma | 118 ma | |
| | | | | $V_{oc}$ | 0.548 V | 0.544 V | 0.538 V | 0.536 V | 0.542 V | |
| | | | | $\eta$ at 0.43 V | 10.4% | 10.3% | 9.8% | 9.2% | 9.6% | |
| | | T4-15 | 3 | $I_{sc}$ | 133 ma | 134 ma | 130 ma | 130 ma | 130 ma | |
| | | | | $I_{0.43}$ | 129 ma | 129 ma | 122 ma | 114 ma | 117 ma | |
| | | | | $V_{oc}$ | 0.562 V | 0.555 V | 0.550 V | 0.548 V | 0.552 V | |
| | | | | $\eta$ at 0.43 V | 10.4% | 10.4% | 9.9% | 9.2% | 9.5% | |
| | | T4-13 | 4 | $I_{sc}$ | 136 ma | 137 ma | 133 ma | 134 ma | 132 ma | |
| | | | | $I_{0.43}$ | 128 ma | 129 ma | 122 ma | 113 ma | 117 ma | |
| | | | | $V_{oc}$ | 0.551 V | 0.549 V | 0.546 V | 0.543 V | 0.550 V | |
| | | | | $\eta$ at 0.43 V | 10.4% | 10.4% | 9.9% | 9.1% | 9.5% | |
| 2 | 20°C | T4-18 | 1 | $I_{sc}$ | 136 ma | | 136 ma | 135 ma | 137 ma | 135 ma |
| | | | | $I_{0.43}$ | 129 ma | | 125 ma | 114 ma | 118 ma | 124 ma |
| | | | | $V_{oc}$ | 0.553 V | | 0.543 V | 0.536 V | 0.540 V | 0.545 V |
| | | | | $\eta$ at 0.43 V | 10.4% | | 10.1% | 9.2% | 9.6% | 10.0% |
| | | T4-20 | 2 | $I_{sc}$ | 136 ma | | 135 ma | 134 ma | 134 ma | 132 ma |
| | | | | $I_{0.43}$ | 128 ma | | 119 ma | 111 ma | 118 ma | 119 ma |
| | | | | $V_{oc}$ | 0.549 V | | 0.538 V | 0.533 V | 0.541 V | 0.542 V |
| | | | | $\eta$ at 0.43 V | 10.4% | | 9.6% | 9.0% | 9.6% | 9.6% |
| | | T4-21 | 3 | $I_{sc}$ | 138 ma | | 136 ma | 135 ma | 135 ma | 134 ma |
| | | | | $I_{0.43}$ | 130 ma | | 125 ma | 110 ma | 118 ma | 119 ma |
| | | | | $V_{oc}$ | 0.551 V | | 0.543 V | 0.537 V | 0.545 V | 0.544 V |
| | | | | $\eta$ at 0.43 V | 10.5% | | 10.1% | 8.9% | 9.6% | 9.6% |
| | | T4-22 | 4 | $I_{sc}$ | 136 ma | | 134 ma | 133 ma | 133 ma | 132 ma |
| | | | | $I_{0.43}$ | 130 ma | | 118 ma | 108 ma | 119 ma | 120 ma |
| | | | | $V_{oc}$ | 0.553 V | | 0.547 V | 0.542 V | 0.550 V | 0.549 V |
| | | | | $\eta$ at 0.43 V | 10.5% | | 9.6% | 8.7% | 9.6% | 9.7% |
| 3 | -196°C | T4-26 | 1 | $I_{sc}$ | 133 ma | | 133 ma | 133 ma | 133 ma | |
| | | | | $I_{0.43}$ | 128 ma | | 121 ma | 114 ma | 115 ma | |
| | | | | $V_{oc}$ | 0.554 V | | 0.546 V | 0.539 V | 0.543 V | |
| | | | | $\eta$ at 0.43 V | 10.4% | | 9.8% | 9.2% | 9.3% | |
| | | T4-27 | 2 | $I_{sc}$ | 136 ma | | 134 ma | 135 ma | 133 ma | |
| | | | | $I_{0.43}$ | 129 ma | | 123 ma | 114 ma | 118 ma | |
| | | | | $V_{oc}$ | 0.550 V | | 0.543 V | 0.538 V | 0.544 V | |
| | | | | $\eta$ at 0.43 V | 10.4% | | 10.0% | 9.2% | 9.6% | |
| | | T4-28 | 3 | $I_{sc}$ | 134 ma | | 132 ma | 133 ma | 132 ma | |
| | | | | $I_{0.43}$ | 129 ma | | 123 ma | 116 ma | 119 ma | |
| | | | | $V_{oc}$ | 0.552 V | | 0.545 V | 0.541 V | 0.548 V | |
| | | | | $\eta$ at 0.43 V | 10.4% | | 10.0% | 9.5% | 9.6% | |
| | | T4-25 | 4 | $I_{sc}$ | 138 ma | | 136 ma | 135 ma | 135 ma | |
| | | | | $I_{0.43}$ | 130 ma | | 122 ma | 115 ma | 120 ma | |
| | | | | $V_{oc}$ | 0.553 V | | 0.547 V | 0.544 V | 0.549 V | |
| | | | | $\eta$ at 0.43 V | 10.5% | | 9.9% | 9.3% | 9.7% | |

## 2.6 Equipment

The dc sputtering system has been modified for rf sputtering. A 7-inch silicon cathode was fabricated by bonding the silicon to a copper cooling plate with a conducting epoxy OHMEX-Ag.

A 1 kW rf induction heating power supply was coupled to the sputtering electrode. Impedance matching was not accomplished and although a glow discharge could be initiated, insufficient voltage could be obtained for significant sputtering.

Modifications in the coupling system as well as a voltage monitoring system are being made on this system. The silicon cathode is temporarily being replaced with a quartz cathode until the system problems are resolved.

In addition to modification to existing equipment, an evaluation of commercially available sputtering equipment is being conducted.

# SECTION 3

# FUTURE PLANS

Work will continue on deposition techniques for producing thick integral coverslips. Equipment problems should be essentially solved on both the high vacuum sputtering system and rf sputtering system. It is anticipated that a decision will be made next quarter on the company acquisition of a new rf sputtering system to support the reactive sputtering work.

Electron irradiations of the cover glass samples used in the optical analysis are scheduled for the next quarter.

# APPENDIX A

## OPTICAL ANALYSIS TECHNIQUE

Transmission samples were prepared on 1 x 2 cm by 1/32 inch thick silica microscope slides that were mounted in the same manner (silicone grease or tape) as the cells. The $SiO_2$ film thickness was inferred from the coverslip thickness of cells surrounding the transmission samples. The transmission data was taken on a Cary Model 14 spectrophotometer operated in the double beam mode with an uncoated piece (1/32 inch thick) of Corning No. 7740 fused silica in the reference beam. The instrument was balanced to 100% T (transmission) with another piece (1/32 inch thick) of fused silica in the sample compartment. For both the VIS-UV and the near-IR portions of the spectrum, the 100% T was set at 800 mμ.

In order to minimize light scattering effects in the VIS-UV portion of the spectrum, the samples were mounted against the end of the cell holder nearest the phototube. To minimize reflection loss differences between the coated samples and the blank, the samples were mounted with the deposited film facing the phototube. After the data was taken, it was realized that this mounting position maximizes light scattering and reflection loss (if present) effects in the near-IR region since the light path through the instrument is reversed for this region. This error accounts for the 1-3% lower transmission, at 800 mμ, of the near-IR scans as compared to the VIS-UV scans. The difference is probably all due to light scattering since the refractive index of high vacuum sputtered $SiO_2$ has been found to be identical, within experimental error to that of bulk fused silica. (This would cause reflection loss differences to be minimal. )

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